Performance Evaluation of Brewery Waste Water Treatment Plant

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Abstract

Present research study was conducted for a period of three months to evaluate each and every phase of industry's waste water treatment processes as a cumulative research. The quantity and quality of brewery waste water fluctuates significantly, depending upon operations like raw material handling, wort preparation, fermentation, filtration, controls in process (CIP) and packaging. The water discharged is found highly organic in nature with high COD consisting of easily biodegradable sugars, soluble starch, ethanol and volatile fatty acids. The paper aims to study the performance evaluation of ETP of M/s Carlesberg India Ltd. a brewing industry located in Paonta Sahib, Himachal Pradesh, India. By feeding influent with controlled input parameters like pH, TSS and COD in UASB reactor, considerable reductions in the pollution loads were achieved. It was also found that improved removal efficiencies and lower electricity consumption are achieved by maintaining mixed liquor suspended solids (MLSS), dissolved oxygen (DO) and controlled oxygenation in the aerobic treatment. The performance evaluation has indicated that 96-98% COD removal, 93-98% TSS removal and 99% BOD removal efficiencies have been achieved. The replacement of existing Activated Sludge Process (ASP) with latest treatment technologies like i.e. Sequential Batch Reactor (SBR) and Membrane Process has been suggested as additional measures in order to achieve the target of less power and space requirement apart from meeting the effluent discharge standards in breweries.

Key Words

Chemical Oxygen Demand (COD); Mixed Liquor Suspended Solids (MLSS); Dissolved Oxygen (DO); Biological Oxygen Demand (BOD) Up Flow Anaerobic Sludge Blanket Reactor (UASBR); Sequential Batch Reactor (SBR)

Introduction

Breweries are the traditional industries in agro and food sector using cost effective techniques to manufacture the best quality product. During the process, beer alternatively passes through three chemical and bio-chemical reactions (mashing, boiling, fermentation and maturation) and three solid–liquid separations (wort separation, wort clarification and rough beer clarification). Consequently, the water consumption, wastewater generation and solid-liquid separation offer real economic opportunities for the overall improvements in the processes of brewing industries. Wastes generated include glass, paper, card board, plastics, oils, wood, biological sludge, green residues and other industrial solid wastes, while the surplus yeast and spent grains are generated as by products. Brewer's spent grains are used for production of low grade compost, livestock feed or disposed off in landfill as waste (Jay et al., 2004). Alternatively, the spent grains can be hydrolysed to produce xylo-oligosaccharides (probiotic effect), xylitol (sweetener) or pentose-rich culture media (Carvalheiro., 2004 and Duarte., 2004). The mass and water balance is very important for optimization of water consumption, minimizing waste water and conservation of energy. In terms of water management, strict legislations are enforced to reduce water consumption and waste water generation using water management practices. For example, waste water to beer ratio is around 2.0 m^3/m^3 (based on mass balance) which is difficult to achieve, because part of water is disposed off as by-products and lost by evaporation (Drissen., 2003 and Vereijken., 2003). The effluents discharged are found to have high organic and acidic content, which increases the BOD, COD and high organic load in the waste water contributive to dissolved carbohydrates, alcohols, suspended solids, yeast etc, which pollutes the water bodies considerably (Chaitanya kumar et al., 2011).

In the brewery industry at Paonta Sahib (H.P), India activated sludge process initially used in 1997 is suffering from high energy requirements for the aeration and inconsistency in achieving the effluent standards. Accordingly, the pre aerobic treatment has been replaced with the Up flow Anaerobic Sludge

Blanket Reactor (UASBR) in the year 2010 with the advantage of not only achieving effluent quality as per Central Pollution Control Board (CPCB) norms but 50% reduction in energy demands. In order to meet demanding requirement of surface water quality, an aerobic polishing after anaerobic pre treatment is suggested. The present paper aims to evaluate performance of brewery industry waste water based on field data and to explore the possibilities of resource recovery from the effluent treatment plant of 400 m^3/ day capacity in Paonta Sahib (HP) India. The overall BOD, COD and TSS removal efficiencies in the effluent treatment plant depends on satisfactory performance of UASB. Combination of anaerobic pre-treatment with aerobic post treatment integrates the advantages of reduced energy consumption and limited space requirement.

About Brewery Industry

M/s Carlesberg India Ltd located in village Tokiyon at a distance of 18 kms from Paonta Sahib (HP) was selected for the present study. The industry is manufacturing beer using rice, malt and yeast as raw material. The effluent treatment plant ETP selected for the present study (400 m^3/day capacity) consists of buffer tank, UASBR, Primary plate separator, Aeration tanks, SAFF reactor, parallel plate separator, Sand filter, activated carbon filter and sludge drying beds as shown in Figure 1.

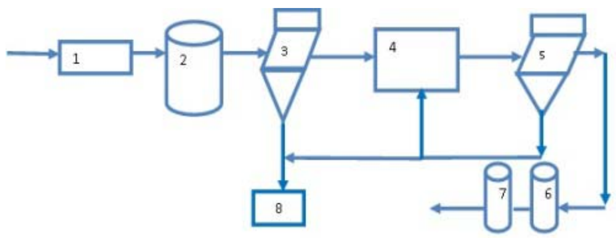

FIGURE 1 FLOW CHART OF ETP

1Collection Tank 2 UASB Reactor 3 Primary Plate Settler 4 Aerobic Treatment Tanks 5 Secondary Parallel Plate Settler 6 Sand Filter 7 Activated Carbon Filter 8 Sludge Drying Beds.

Materials and Methods

From June 2012 to Sep 2012 (three months), the waste water samples were collected by grab sampling using sterilized one litre plastic bottles. The sampling was done from UASB reactor, aeration tank, parallel plate separator (secondary) and at the outlet of activated carbon filter for physicochemical analysis for pH, Total suspended solids (TSS), Total dissolved solids (TDS), Volatile fatty acids (VFA), COD, BOD, alkalinity and dissolved oxygen (DO). All samples were transported and analysed in the State Pollution Control Board laboratory at Paonta Sahib as per standard methods (American Public Health Association, 1993). Table 1 gives the capacities of different units of ETP.

TABLE 1 CAPACITY OF DIFFERENT UNITS OF ETP

S. N.	Treatment Unit	Capacity in m^3	Retention Time (hrs)	Electrical Power Consumption (Kwh)
1	Equalization Tank(Buffer Tank)	380	23	2.98
2	UASB Reactor	270	17	2.24
3	Primary Plate Separator (PPS)	20	1.5	-
4	Aeration Tank	380	23	7.46
5	Secondary Plate Settler (SPS)	20	1.5	-
6	Tertiary Treatment Pressure Sand Filter(PSF) and Activated Carbon Filter (ACF)	15	1	-
7	Final Outlet	10	1	1.49
8	Sludge Drying Bed	-	15 Days	1.20

The treatment units i.e. buffer and aeration tanks have much higher capacities and the treatment process is combination of anaerobic pre-treatment with aerobic post treatment. The effluent is fed for anaerobic treatment after being collected in buffering tank which is used to balance the variations in organic loads, pH and flow resulting from batch operation of brewing process as well as the dilution of toxic and inhibiting compounds from the processing plants.

Data Collection and Processing

For statistical analysis, the COD and BOD on weekly basis at inlet and outlet of ETP have been taken into

consideration. As the mean of COD and BOD at influent varies in the range of 3500-5000 mg/l and 1200-3000 mg/l, while after treatment it varies in the range of 8-18.5 mg/l and 78-128 mg/l, respectively, the standard deviation (SD) and coefficient of variation (CV) are calculated and presented in the Table -2 and the fluctuations in pollution load are assessed at inlet and outlet of ETP.

The results of table reveal that at the inlet of ETP the COD has the highest mean in the 9th week and the lowest in the 11th week and CV shows that all COD values except in 4th, 6th, 9th and 13th week are heterogeneous in nature and therefore regular monitoring is required for achieving better efficiencies of UASB for methane generation.

BOD at the inlet of ETP has the highest mean value in the 10th week and the lowest in the 11th week and the CV in all BOD values except in 3rd, 4th, 5th,12th and 13th week shows much variation and so the regular monitoring is required for better treatment efficiencies. At the final outlet of ETP, the COD has highest mean in 11th week and lowest in 3rd week with CV except in 2nd, 3rd and 9th week are heterogeneous, and hence routine monitoring is required for better efficiencies of biological treatment, whereas in case of final outlet of ETP, the BOD is the highest in the 13th week and the lowest in the 7th week and with CV of BOD except 1st, 3rd , 4th and 6th week, is heterogeneous in nature showing thereby the need of routine monitoring for checking the efficiency of tertiary treatment. Further, the BOD and COD values at final discharge are within permissible limit of standard prescribed under EPA rules as detailed in Table 3.

The performance of anaerobic, aerobic and tertiary treatment was monitored by analysing the samples collected from inlet and outlet of anaerobic digester, inlet and outlet of aerobic treatment and final outlet after tertiary treatment.

Performance of UASB

The UASB is the main treatment unit for overall COD and BOD removal with formation of granular sludge bed due to higher VSS loadings. The UASB loading was evaluated by measuring its feed rate and discharge of waste water and comparing it with optimum reactor loadings. The variations of volumetric loadings with % age reductions of COD in UASB is given in Table-4 which shows that COD of influent varies between 3565 to 4840 mg/l and inflow to the reactor is almost uniform. The volumetric loadings to the reactor are in range from 4.77-6.93 kg COD/m^3 day against recommended volumetric loadings between 2-6 kg COD/m^3 day in the UASB for high TSS and COD removal efficiencies between 92-95% and 77-84% respectively. The removal efficiencies of BOD, COD by the UASB reactor are shown in the Figure 3.

The high BOD and COD removal efficiencies in the UASB are 90-94 and 93-95% respectively, which may be due to proper functioning of the reactor. The BOD/COD ratio ranges from 0.3-0.6 due to the fluctuations in inflows, quantity and quality of the effluent and is a function of various processes like brewing, fermentation and clarification etc. The unit also satisfies the waste management requirements by implementing cleaner technologies. The spent grains are sold as livestock feed.

The % reduction in TSS in the UASB reactor over the study period is shown graphically in Fig-4. TSS removal efficiencies between 77-84% can be attributed to the higher VSS resulting in the formation of granular sludge bed in the UASB. There is decrease of total suspended solids TSS as shown in the Figurer 4. Although settle able solids are often problem in breweries, however, the removal rate was observed on higher side in later period of study and need to be monitored on regular basis during the treatment process.

Overall Performance of ETP

The overall percentage reduction of COD, TSS and BOD in the Effluent Treatment Plant has been shown in the Table 5.

The results in the table indicate that COD, BOD and TSS meet the discharge standards. During the study of brewery's waste water treatment plant, it has been observed that overall removal efficiencies of COD, TSS and BOD are found as 96-98%, 88-98% and 99% respectively which is mainly due to considerable reduction of pollution load in the UASB reactor operated under controlled parameters using buffering tank to balance the variations in organic loads and pH. The value of pH at final outlet has been observed in the range of (7.09-7.28) which is within the limit prescribed (5.5-9.0) under rules. The remaining treatment units i.e. aeration tank, pressure sand filter and activated carbon filter also work properly giving consistent results at the final outlet of ETP.

TABLE 2 STATISTISTCAL ANALYSIS OF COD AND BOD DATA

Period	COD(mg/l)						BOD(mg/l)					
	Inlet of ETP			Final Outlet of ETP			Inlet of ETP			Final Outlet of ETP		
	Mean	SD± mean	CV (%)	Mean	SD± mean	CV (%)	Mean	SD± mean	CV (%)	Mean	SD± mean	CV (%)
Week 1st	4620	372	8	99	3.5	3.6	2928	237. 9	8.12	14.4	2.70	18.65
Week 2nd	4248	521	12	92.2	12.6	13.7	2619	97.6	3.72	9	1.41	15.71
Week 3rd	3787	600	16	78	10.5	13. 5	1490	21.2	1.42	8	1.40	17.67
Week 4th	3963	406	10	105	17.2	16.5	2069	33.2	1.60	15	2.83	18.85
Week 5th	3842	783	20	104	12.1	11.7	2101	36.76	1.75	14	1.40	10.1
Week 6th	4447	462.8	10	93	16.3	17.5	1901	741	38.98	16	2.83	17.67
Week 7th	3990	861.4	21	89	7.9	8.9	1930	17	0.878	9.9	0.85	8.56
Week 8th	3993	659.6	17	105	10.4	9.9	1978	335.9	16.98	15.4	5.51	35.88
Week 9th	4840	450.6	9	106	13.4	12.7	2555	714.2	27.95	18.5	2.12	11.46
Week 10th	4665	727	16	104	16.2	15.6	3000	169.2	5.64	8	2.83	35.35
Week 11th	3565	846	24	128	25.2	19.7	1173	598.2	50.99	12.55	1.34	10.7
Week 12th	3846	691.6	18	102	21.1	20.7	1275	319	24.95	10	1.41	14.14
Week 13th	4187	395	9	121	10.8	8.9	2229	581.24	26.07	16.6	1.13	6.81

SD: Standard Deviation, CV: Coefficient of Variation

TABLE 3 DISCHARGE STANDARDS FOR FERMENTATION INDUSTRY

Industry	Parameter	Concentrations in the effluents not to exceed milligrams per litre(except for pH, colour & odour
Fermentation Industry (Distilleries, Malteries and Breweries)	pH	5.5-9.0
	Colour & Odour	All efforts should be made to remove colour and unpleasant odour as for as practicable
	Suspended Solids	100
	BOD(3days at 27° C) disposal into inland surface waters or river streams	30
	Disposal On land or for irrigation	100

TALBE 4 VOLUMETRIC LOADINGS WITH COD, BOD AND TSS REMOVAL IN USAB

Period	Flow (m^3/day)	COD (mg/l)		COD removal efficiency	Volumetric Loading Rates (kg COD/m^3.d)	BOD		BOD removal efficiency	TSS(mg/l)		TSS removal efficiency in UASB
		Inlet	Out let			Inlet	Outlet		Inlet	Outlet	
Week 1st		4620	306	93%	6.63	2928	170	94%	721	126	82%
Week 2nd	384	4248	318	93%	6.04	2619	197	92%	798	138	82%
Week 3rd	382	3787	243	94%	5.35	2394	143	90%	972	163	83%
Week 4th	358	3963	237	94%	5.25	2280	148	93%	882	152	77%
Week 5th	384	3842	245	94%	5.46	2516	159	92%	745	129	79%
Week 6th	372	4447	260	94%	6.12	2660	155	92%	623	112	82%
Week 7th	390	3990	263	94%	5.79	2256	167	91%	418	75	82%
Week 8th	392	3993	216	95%	5.8	2199	149	92%	463	81	82%
Week 9th	387	4840	292	94%	6.93	2760	154	94%	512	115	77%
Week 10th	394	4665	317	93%	6.8	3000	190	94%	415	78	81%
Week 11th	362	3565	285	92%	4.77	2118	169	90%	441	75	83%
Week 12th	377	3846	250	93%	5.37	1872	146	89%	240	41	83%
Week 13th	379	4187	282	93%	5.87	2229	169	92%	221	34	84%

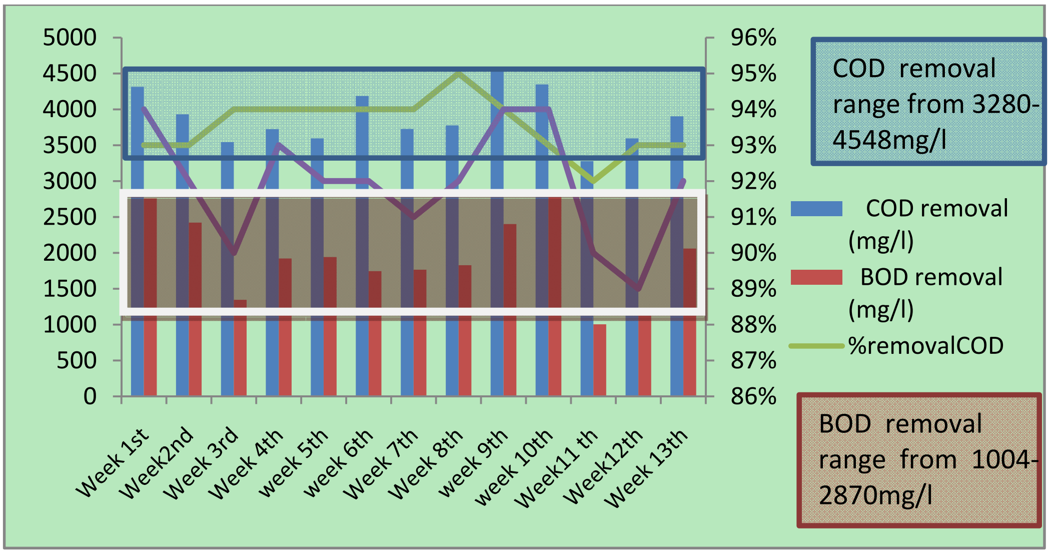

FIGURE 3 BOD AND COD REMOVAL EFFICIENCIES IN UASB

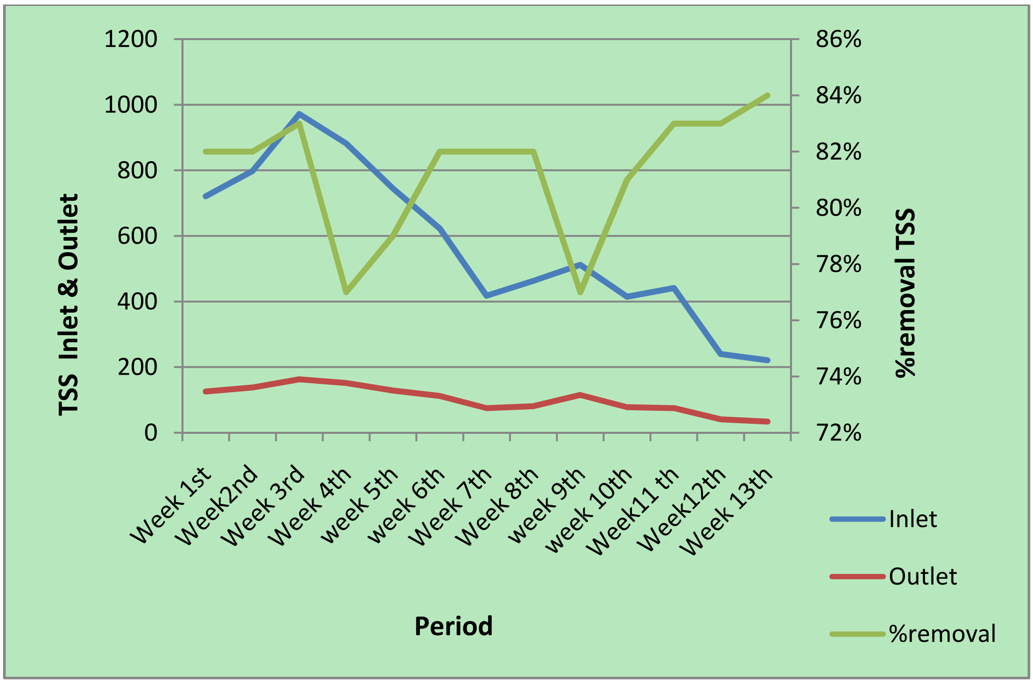

FIGURE 4 TSS REMOVAL EFFICIENCIES IN UASB

TABLE 5 OVERALL REDUCTIONS OF COD, TSS AND BOD

Period	TSS			BOD			COD		
	Inlet (mg/l)	Outlet (mg/l)	% removal	Inlet (mg/l)	Outlet (mg/l)	% removal	Inlet (mg/l)	Outlet (mg/l)	% removal
Week 1st	721	23.33	97%	2928	26.5	99%	4620	99	98%
Week 2nd	798	17.5	98%	2619	25.5	99%	4248	92.2	98%
Week 3rd	972	22	98%	2394	17.6	99%	3787	78	98%
Week 4th	882	22	97%	2280	25	99%	3963	105	97%
Week 5th	745	15	99%	2516	17.15	99%	3842	104	97%
Week 6th	623	23	96%	2660	22	99%	4447	93	98%
Week 7th	418	35.5	95%	2256	9.9	99%	3990	89	98%
Week 8th	463	25	95%	2199	20.4	99%	3993	105	97%
Week 9th	512	26	95%	2760	18.5	99%	4840	106	98%
Week 10th	415	23	95%	3000	8	99%	4665	104	98%
Week 11th	441	25	94%	2118	12.55	99%	3565	128	96%
Week 12th	240	17	93%	1872	10	99%	3846	102	97%
Week 13th	221	26	88%	2229	16.6	99%	4187	120	97%

TABLE 6 SUMMARY OF UASB AND OVERALL ETP PERFORMANCE

S. N.	Parameters	Performance of UASB	Overall Performance of ETP
1	TSS	77-84%	88-99%
2	BOD	89-94%	99%
3	COD	92-95%	96-98%
4	Volumetric Loadings	4.77- 6.93 kg COD/m^{3}day	Loadings recommended (2-6) kg COD/m^{3}day

The removal efficiencies shown in summarised table indicate that ETP works properly and can be role model for other breweries.

Conclusions

The performance of ETP installed in M/s Carlesberg India Ltd Paonta Sahib has been found to give high COD, BOD and TSS removal efficiencies. The treated effluent water is found to meet the effluent discharge standards. In order to further improve the performance of the ETP, the following action plans are recommended. The above study recommended to following action plan for the resource recovery to make ETP sustainable for conservation of energy and water.

- The secondary settling rates may be enhanced with provision of regular sludge recirculation in aeration tanks and to maintain optimum level of MLSS.
- Existing conventional activated sludge process may be modified to SBR for saving power and making the treatment sustainable.
- The methane from UASB should be used as fuel in the boiler to reduce pet coke consumption used presently as fuel.
- The treated effluent from the ETP should be recycled for non potable use and in order to reduce the dependency on the fresh water supply.

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